Chapter 2 Conceptual Framework

2.1 Introduction

With the inception of studies of evolutionary economics, the scope of innovation analysis has been broadened from artefacts to systems, from single event to continuous process, and from organisations to networks of organisations. Also, ranging from the micro to the macro environment, the research agenda of innovation studies has responded to influencing, driving and constraining factors of innovation processes on various levels of analysis. In this regard, the sectoral-level of innovation analysis, among others, is counted as one of the key variants in the innovation systems library.

This chapter establishes the conceptual framework used in this study and details various perspectives on technological innovation activities at the sectoral-level. It is presented in four parts. The first part describes the interactive and progressive nature that underlies the process of technological innovation. The elements of technological innovation and its consequences for firm-level technological innovation management and measurement are subsequently elaborated. Based on this foundation, the second part discusses the three main building blocks of the Sectorial Innovation Systems (SIS) framework. It is postulated that the pattern and process of technological innovation are highly idiosyncratic at the sectoral-level. The third part analyses the sectoral patterns of innovation in the LMT. Since Malaysia's wooden furniture industry is made up largely of SMEs, the final part of this chapter will draw attention to various roles of SMEs in technological innovation activities at the sectoral level. The nature of linkage capabilities and social capital are also elaborated at the end of this chapter.

2.2 Nature of Technological Innovation

In this section, a brief review on the nature of technological innovation is presented in three parts. The first part reviews the inter-disciplinarity, complexity, integration and evolutionary nature of technological innovation activities. The second part reviews the elements and management perspectives of technological innovation. This is followed by the reviews of types of activities and the measurement of technological innovation.

2.2.1 Inter-disciplinarity, Complexity, Integration and Evolutionary

An extensive review of literature suggest that technological innovation, whether economic or social centred, is not an isolated event or within the realm of one particular discipline.[7] Likewise the management literature, technological innovation is subject to a considerable amount of research that crosses traditional boundaries between various disciplines, among them psychology, sociology, social anthropology, economics, economic history, engineering, geography, public policy, marketing and corporate strategy (Grønhaug & Kaufmann, 1988). Such inter-disciplinarity, according to Betz (2003), is basically drawn from the nature of technological innovation that bridges two very different worlds – the technical world which runs on laws of nature and the

[7] For instance, Fagerberg (2005) contends that such inter-disciplinarity of innovation studies has been clearly manifested in the establishment of Science Policy Research Unit at the University of Sussex in 1965, which has an inter-disciplinarity research staff consisting of researchers with backgrounds in subjects as diverse as economics, sociology, psychology, and engineering.

business world which runs on laws of economy. In other words, technological innovation is by nature a highly socio-economic-technical hybrid. This is why according to Malecki (1997) and Köhler (2008), innovations encompasses all dimensions of economic activities and take place in all sectors, regions and types of firms. Therefore, the success of innovation no longer depends on individual investors but on systematic laboratory research, an educated workforce, and a knowledgeable management which integrate technology and market in a complex combination.

Following the principle of inter-disciplinarity, the term "technology" in technological innovation studies, as reflected in some of the studies of Fisher (1975), McGinn (1991), Sundbo (1996) and Ettlie (2000), has been defined from a broader spectrum. What is shared amongst these studies is that the realm of technological activities in this context encompasses the theoretical and practical knowledge, skills, and artefacts that can be used to develop products and services as well as their production and delivery system. In this regards, technology can be embodied in people, materials, cognitive and physical processes, plants, equipment, and tools. Besides, another perspective on technology is given by Gaynor (1996) whose work has established three manifestations of technology alongside the principle of inter-disciplinarity. Firstly, he proposes that technology, which includes whatever is needed to convert resources into products or services, is the means for accomplishing a task. Secondly, technology includes the knowledge and resources that are required to achieve an objective, and thirdly, technology is the body of scientific and engineering knowledge which can be applied in the design of product and / or processes or in the search for new knowledge.

The inter-disciplinarity of technological innovation as discussed above logically leads to other characteristics of technological innovation activities, that is, complexity and integration. Studies by Kline & Rosenberg (1986) and Mowery (1995) argue that since the linear view of the innovation process that has underpinned the traditional approach of innovation studies is no longer relevant in today's context, the process of innovation is more accurately portrayed as a set of interactive activities that include scientific, technological, design and engineering research and practice, which link to one another through complex feedback loops rather than a sequence of phases or steps. More precisely, most innovation is non-unidirectional, dynamic, recycling between stages, jumps out of sequence, and messy. A single technological innovation is a trajectory that consists of many small events, and the result of a lengthy process involving many interrelated innovations. For them, this is one of the reasons why in most cases the systemic approach rather than the focus exclusively on individual innovation has been applied in innovation studies. A successful innovation always relies on the nexus among different activities, and the keyword for this interaction is integration. As Kline & Rosenberg (1986) assert:

> It is a serious mistake to treat an innovation as if it were a well-defined, homogenous thing that could be identified as entering the economy market at the precise date – or becoming available at the precise point in time – The fact is that most important innovations go through drastic changes in their lifetimes – changes that may, and often do, totally transform their economic significance. (p. 283)

In the same vein, Tress, Tress & Fry (2004) also state:

> By integration we mean that different knowledge cultures are bridged and their knowledge fused together when answering a research question. As different knowledge cultures, we might consider the natural sciences, social sciences and humanities, disciplines using quantitative versus qualitative approaches or disciplines that have different concepts of data and validation. (p. 18)

To complement the discussions on the nature of technological innovation, changes that arise from technological change have been widely discussed though biological analogies. There are similarities between the evolution of technological systems and the evolution of organisms that are heavily based on the evolutionary theories. For Malecki (1997), the instability or disequilibrium and variety found in reality are the strengths of the evolutionary theories. Nelson & Winter (1982) are considered by many to be at the forefront in the evolutionary theory-building movement in economic and technology development, particularly through the introduction of the term “routine”, or “all regular and predictable behaviour patterns of firms.” According to Marleba & Brusoni (2007), these routines are not fixed, but can be changed over time, especially so under the influence of feedback from economic performance. Nelson & Winter (1982) take the discussion one step further to the firm-level. Within organisational theory, they argue that firms which have better routines for research, production, marketing and management generally will prosper and grow relative to those firms whose capabilities and behaviour are less well suited to the current situation.

The core emphasis of evolutionary theory is on the dynamic process by firm behaviour patterns and market outcomes are jointly determined over time (Ettlie, 2000). In other words, firms' learning process and technological accumulation are the core elements under the focus of evolutionary theory. Frenken (2006) contends that:

> Taking the artefact as the unit of analysis, the process of technological evolution can be viewed as a succession of artefacts, the design of which evolves through trial-and-error learning. This process is evolutionary in that learning takes place by trials of alternative solutions, comparisons based on relative merits, and differential reproduction favouring the solutions that have been relatively successful. (p. 3)

Taking this as the starting point, the following section provides a closer look at the translation of the understanding of the nature of technological innovation into the management perspective of technological innovation.

2.2.2 Elements of Innovation and Management Perspectives

Given that technological innovation is inter-disciplinary, complex and grounded on the evolutionary theory, any comprehensive research in this field must take into account the full spectrum of the innovation process, which is, ranging from idea generation, to the conversion and exploitation of this idea into useful application in the market. In this context, the technological change process, as eloquently summed up by Stoneman (1995), which is extensively drawn from Schumpeter's trilogy, is divided into three main stages. The first stage is the invention process, encompassing the generation of new ideas. The second stage is the innovation process encompassing the development of new ideas into marketable products and processes. The third is the diffusion stage, in which the new products and processes spread across the potential market. A somewhat similar idea has been articulated in studies by Dodgson (2000), Thamhain (1996), Patterson (1996) and Janzen (2000). Chiesa (2007) makes this point clearer:

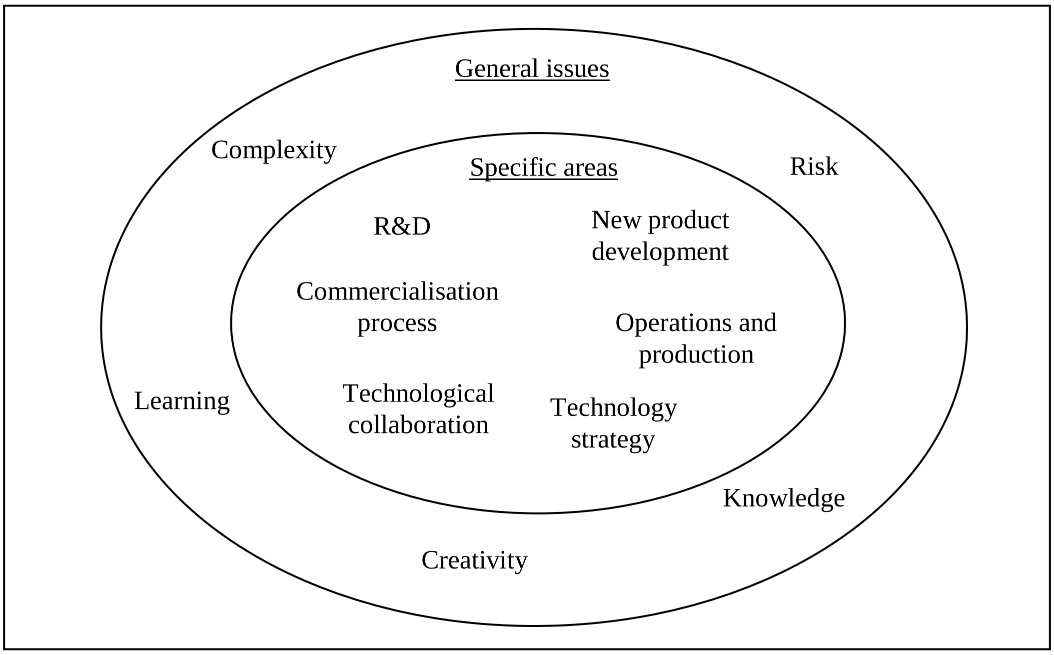
> The overall management of technological innovation includes the organisation and direction of human and capital resources towards effectively fulfilling all these activities: (i) creating new knowledge, (ii) generating technical ideas aimed at new and enhanced product, manufacturing processes and services, (iii) developing those ideas into working prototypes, and (iv) transferring them into manufacturing, distribution and use. (p. 3)

Additionally, Patterson (1996)'s so-called "innovation engine" suggests that opportunity scanning, product definition and planning, manufacturing development, product development, and market development are the main elements for this innovation engine. Every element is a cross-functional process, and many of the elements are executed concurrently. Thus to succeed in innovation, a firm needs to combine several different types of knowledge, capabilities, skills and resources. For instance, the firm may require production knowledge, skills and facilities, market knowledge, a well-functioning distribution system, sufficient financial resources, and so on.

Thamhain (1996) and Janzen (2000) also reached similar consensus. For Thamhain (1996), innovative activities include the basic organisation of tool, techniques, and systems to managing the innovation efforts, such as planning, budgeting, directing, scheduling, motivating, and task integrating. Innovation, especially in a technology-based environment, cannot be confined to selected organisations but must be encouraged and nurtured at all levels and with all people. In addition, to deal with this wide spectrum of technological innovation activities, Janzen (2000) has defined the combination of four aspects of innovation, namely introducing new technologies (T), new applications in the form of new products and services (A), the development of new markets (M) and / or the introduction of new organisational forms (O) – to increase net value for customers and, eventually, their loyalty. The TAMO combination is an extension of the well-known technology, product and market combination that reflects the holistic nature of successful innovation management.

To summarise, since technological innovation activities encompass various disciplines such as the scientific, technological, organisational, financial and business activities leading to the commercial introduction of a new (or improved) product, production process or equipment, the management of technological innovation has to encompass both the specific areas and general issues (Dodgson, 2000). As illustrated in Figure 2:1, management of R&D, new product development, operations and production, commercialisation process, technological collaboration and technology strategy are specific areas of technological innovation management; while complexity, risks, knowledge, creativity and learning are general issues related to the management of technological innovation.

Figure 2:1 Management of technological innovation: specific and general issues



Source: Dodgson (2000)

2.2.3 Types of Activities and Measurements

Technological innovation activities are generally categorised into two types – technological product innovation and technological process innovation.[8] The Oslo Manual, which is the guideline for collecting and interpreting innovation data established by the OECD (1997), cites TPP innovation activities as:

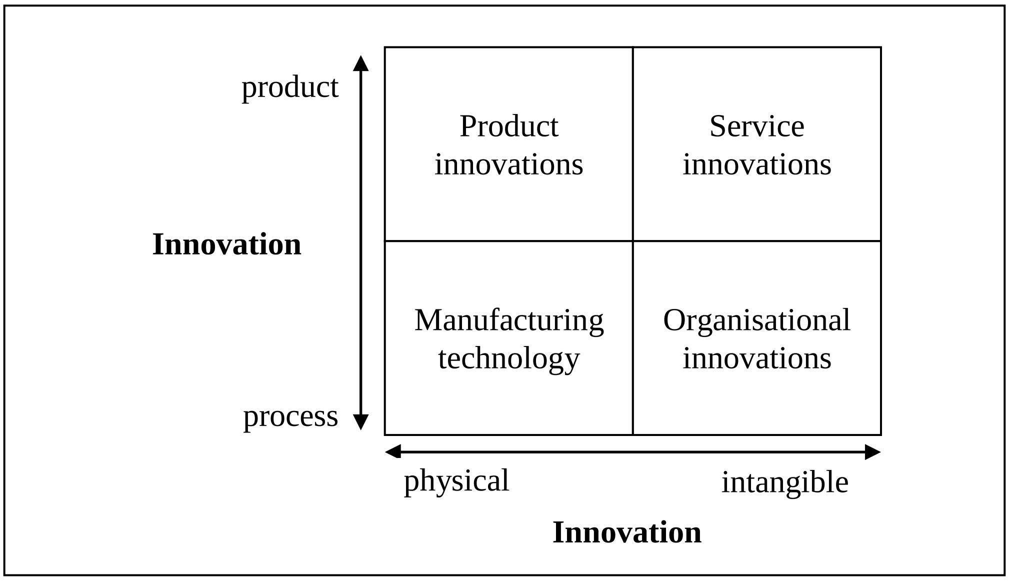
[8] Various types of innovation have been proposed by different scholars. For instances, Schumpeter (1934) suggests that there are five types of innovation, namely the introduction of a new product or a qualitative change in an existing product; process innovation new which is to an industry; the opening of a new market; development of new sources of supply for raw materials or other inputs; and changes in industrial organisation. According to the OECD (2005), innovation can be categorised into four types, namely innovation in terms of product, process, market and organisational.

> … all those scientific, technological, organisational, financial and commercial steps, including investment in new knowledge, which actually, or are intended to, lead to the implementation of technologically new or improved products or processes. (p. 10)

The term "product" in this sense is used to cover both goods and services. As such, a technological product innovation is the implementation or commercialisation of a product with improved performance characteristics designed to deliver objectively new or improved services to the consumer. A technological process innovation is the implementation or adoption of new or significantly improved production or delivery method. It may involve changes to equipment, human resources, working methods or a combination of these (OECD, 1997).[9] A somewhat similar view has been advanced in the study by Kirner, Kinkel & Jaeger (2009) at the manufacturing firms. In this regard, product innovations might consist of either material (physical) or immaterial (intangible) products; and process innovations might involve technological (physical) or organisational (intangible) aspects. Figure 2:2 shows types of innovation activities in manufacturing firms.

[9] According to Stoneman (1995), it is common to separate product innovation and process innovation and the distinction between product and process innovation is a useful one. However, the evidence would tend to suggest that product and process innovation in the real world go hand-in-hand. It should also be noted that one firm's new product innovation may be another firm's new process innovation. Firms may acquire new technology by purchasing that technology embodied in new capital equipment. Then the capital good that embodies the technology is a product, but the buyer is acquiring a process innovation. Moreover, Chiesa(2007) states that an innovation cannot be defined as a product or process in absolute terms. An innovation is a product innovation when it concerns the output of a firm's activity, whereas it is a process innovation when it concerns the means of production used to market the firm's product. Therefore, a product innovation for one firm might be a process innovation for another (Chiesa, 2007; OECD, 1997). One of the typical examples is that of innovative industrial machinery, which is a product innovation for the machinery manufacturer and a process innovation for the firm that buys the machinery and makes use of it.

Figure 2:2 Innovation fields in manufacturing firms.



Source: Kirner, et al. (2009)

Obtaining a consensus on the necessary degree of novelty is always an issue in technological innovation research, especially for those empirical studies which engage with primary data collection. This is because different people with different backgrounds and interests may form different interpretations of the concept of "new or improved" in technological innovation activities. In order to overcome this problem, the Oslo Manual (OECD, 1997, 2005) proposes that the minimum entry requirement for all technological innovations is that the product or process should be new or significantly improved to the firm, but it does not have to be new to the world. Hence, for the purposes of empirical data collection, a technologically innovative firm is one which has implemented new or significantly improved technological products or processes during the period under review. Table 2:1 provides a clear picture on the types and degree of novelty and the definition of innovation.

Table 2:1 Type and degree of novelty and the definition of innovation

			INNOVATION			Not Innovation
			Maximum	Inter-mediate	Minimum	
			New to the world	(a)	New to the firm	Already in firm
TPP INNOVATION	Technologically new	Product	✓	✓	✓	×
		Production Process	✓	✓	✓	×
		Delivery process	✓	✓	✓	×
	Significantly technologically improved	Product	✓	✓	✓	×
		Production Process	✓	✓	✓	×
		Delivery process	✓	✓	✓	×
Other Innovation	New or improved	Purely organisation	*	*	*	×
Not Innovation	No significant change, change without novelty, or other creative improvements	Product	×	×	×	×
		Production Process	×	×	×	×
		Delivery process	×	×	×	×
		Purely organisation	×	×	×	×

TPP innovation ✓ Other innovation * Not innovation ×

Source: OECD (1997)

From the perspective of policymakers, the analysis and measurement of firm-level technological innovation is a crucial tool for them to define the state-of-the-art, perform benchmarking and identify the needs and challenges of the sector. Efforts in improving the measures of innovation is crucial in the sense that measuring innovation is central to understanding the economy as it evolves and responds to growing world competition. In other words, improvements to our measurements of innovation will help to ensure continued economic strength, and at the same time avoid harmful policies besides enactment of facilitative policies (OECD, 1997, 2005, U.S. Department of Commerce, 2008). In line with this viewpoint, some of the important parameters for the analysis measurement of firm-level technological innovation, as advanced by OECD (1997, 2005), are given below:

a) *Components and coverage* - Innovation activities may be carried out within the firm, or may involve the acquisition of goods, services or knowledge from outside sources. The acquisition of technology may be in disembodied or embodied form. Some of the key components of TPP innovation activities are: (i) conducting in-house R&D, (ii) acquisition of external R&D, (iii) purchase or licensing of patents and non-patented innovation, know-how and other types of external knowledge from other companies or organisations, (iv) acquisition of machinery, equipment and software in connection with product and process innovation, (v) conducting industrial, product, process and service design and specifications for production or delivery, (vi) marketing preparation, and (vii) training for personnel directly related to innovation activity.

b) *Objectives* – Firm-level technological innovation activities are mainly based on economic objectives. For instance, technological innovation activities are largely linked with the firm's efforts in enhancing the competitiveness level of products and increase the efficiency of the productivity. However, technological innovation activities in some cases are aimed at reducing the environmental damage and promoting firm to be more accountable for their environmental responsibilities.

c) *Assisting and hampering factors* - Two sets of factors have been identified, namely (i) the innovation process is assisted by a variety of sources of information: internal sources (within the firm), external market sources, educational and research institutions, and generally available information; and (ii) innovation may be hampered by economic factors, ones relating to the enterprise, and with a miscellany of others.

d) *Linkages* - Linkages act as sources of knowledge and technology for a firm's innovation activity, ranging from passive sources of information to suppliers of embodied and disembodied knowledge and technology to co-operative partnerships. Each linkage connects the innovating enterprise to other actors in the innovation systems: government laboratories, universities, policy departments, regulators, competitors, suppliers and customers. There are three types of linkages or flows of knowledge and technology to a firm, namely (i) open information sources that do not involve purchases of knowledge and technology or interaction with the source, (ii) purchases or acquisition of knowledge and technology; and (iii) innovation co-operation.

Simply stated, a reliable and rigorous analysis and measurement of technological innovation activities must acknowledge the nature of multidirectional and complexity of technological innovation. Realising that the complex interdependencies and integration of the various elements of innovation process is explicitly recognised by the innovation systems approach, the next session provides a comprehensive background of the innovation system approach in the context of sectoral-level innovation study.

2.3 Sectoral Approach of Innovation Systems

This section provides reviews on the sectoral approach of innovation systems in two parts. The first part reviews the main literature on innovation systems framework. The second part reviews the innovation systems framework at the sectoral level, that is, the SIS. The three building blocks of SIS are given in-depth discussions.

2.3.1 Systemic Approaches in Innovation Studies

The literature on innovation systems is extensive and there is a trend where innovation systems have been defined at different levels for different purposes of analysis (Markard & Truffer, 2008). Carlsson, et al. (2002) assert that innovation systems can be viewed in several dimensions. One dimension is the physical or geographical dimension. Sometimes the focus is on a particular country or region which then determines the geographic boundaries of the system. In other cases, the dimension of interest is a sector or technology. Another dimension is that of time, where a snapshot of the system at a particular point in time may differ substantially from another snapshot of the same system at a different time. Despite the extensive literature, studies by Edquist (1997, 2001, 2005) provide a crystal clear perspective on the development of innovation systems and thus increase the usability of the approach for empirical studies.

The pioneering literature on innovation systems was initiated Freeman (1987, 1995), Lundvall (1992) and Nelson (1993) on the perspective of National Innovation Systems. Since then other similar specifications of innovation systems have emerged and are currently used in addition to the national one. The Technological Systems approach by Carlsson (1995) and his colleagues is one of them. In contrast to the National Innovation Systems approach, Carlsson, et al. (2002) talk about technological systems in various specific technological fields. Meanwhile, Breschi & Malerba (1997) similarly focus on a group of firms that develop and manufacture the products for a specific sector and that generate and utilise the technologies of that sector. There are also studies on geographical boundaries of Regional Innovation Systems which study innovative patterns within countries or include parts of different countries, for example, Cooke, Uranga & Etxebarria (1997). Despite their different emphases, these variants share some common characteristics and have been dealt extensively in studies by Edquist and his colleagues, such as Edquist (1997), Edquist & Hommen (1999), and Edquist, Hommen & McKelvey (2001).[10]

2.3.2 Sectoral Innovation Systems and its Building Blocks

The SIS approach, which is grounded on the innovation systems tradition, is based on the theoretical viewpoint that changes in innovation and technology take place at different rates, types and trajectories depending on the sector in which they occur. The notion of SIS complements other concepts within the innovation systems literature (Edquist, 1997). For Malerba (2005), a sector is a set of activities that are unified by

[10] Edquist (1997) detailed seven main common characteristics of innovation systems, namely (i) innovation and learning at the center, (ii) holistic and interdisciplinary, (iii) historical perspective, (iv) differences between systems, rather than the optimality of systems, (v) interdependence and non-linearity, (vi) product technologies and organisational innovation, and (vii) institutions are central.

some linked product groups for a given or emerging demand and which share some common knowledge. Firms in a sector have some commonalities and are, at the same time, heterogeneous.

Multidimensional, integrated and dynamic views are the main concepts of SIS. For Malerba (2005), understanding the key sectors which drive an economy with their specificities greatly helps in understanding national growth and national patterns of innovative activities. He makes this point succinctly:

> A rich and heterogeneous tradition of sectoral studies has clearly shown both that sector differ in terms of the knowledge base, the actors involved in innovation, the links and relationships among actors, and the relevant institutions, and that these dimensions clearly matter for understanding and explaining innovation and its differences across sectors. (p. 381)

Also,

> Heterogeneous firms facing similar production activities, searching around similar knowledge bases, undertaking similar production activities, and 'embedded' in the same institutional setting, share some common behavioral and organizational traits and develop a similar range of learning patterns, behavior, and organization forms. (p. 387)

A sectoral systems framework focuses on three main dimensions (or building blocks) of sectors, namely (a) knowledge, technological domain and sectoral boundaries, (b) actors, relationships and networks, and (c) institutions. Provided below are the detailed descriptions on these three building blocks as advanced by Malerba (2005).

a) *Knowledge, technological domain and sectoral boundaries* – Like other innovation systems approaches, the SIS approach places knowledge at the centre of analysis. Based on Lundvall's (1992) perspective which puts knowledge and interactive learning at the centre of analysis, Marleba (2004) contends that knowledge plays a central role in innovation and is highly idiosyncratic at the firm level. Knowledge does not diffuse automatically and freely among firms, and has to be absorbed by firms through their differential abilities which are accumulated over time. Knowledge differs across sectors in terms of domain specifications and may have different degrees of accessibility and the sources of technological opportunities differ markedly across sectors.[11] As such, Lundvall (1992) reminds us that the knowledge learning process is predominant and interactive, therefore it is socially embedded which cannot be understood without taking into consideration its institutional and cultural context.

   Both knowledge and technologies are eventually affecting the boundaries of sectoral systems. As the accumulation of knowledge and technologies occur within the social systems, the boundaries of sectoral systems are not static.

[11] As Freeman (1982), among others, have shown, in some sectors opportunity conditions are related to major scientific breakthrough in universities; in others, opportunities to innovate may often come from advancements in R&D, equipment, and instrumentation; while still other sectors, external sources of knowledge in terms of suppliers or users may play a crucial role.

Moreover, Malerba's (2004) study made a notable effort to identify three different sources of cumulativeness of knowledge. These three sources are: (i) *Cognitive*, in which the learning processes and past knowledge constrain current research, but also generate new questions and knowledge; (ii) *The firm and its organisational capabilities*, in which organisational capabilities are firm-specific and generate knowledge which is highly path-dependent; and (iii) *Feedback from the market*, such as in the "success-breeds-success" process.[12]

b) *Actors, relationships and networks* – Innovations are collective societal processes with firms as core actors in a networked social context (Köhler, 2008). For Marleba (2004), a sector is composed of heterogeneous agents, comprising organisations or individuals (e.g. consumers, entrepreneurs, scientists). Organisations may be firms (e.g. users, producers, input suppliers) or non-firms (e.g. universities, financial institutions, government agencies, trade-unions, or technical associations), and may include subunits of larger organisations (e.g. R&D or production departments) and groups of associations (e.g. industry associations). Firms are the key actors in the generation, adoption, and use of new technologies, and are characterised by specific beliefs, expectations, goals, competences, and organisation. They are continuously engaged in the processes of learning and knowledge accumulation (Malerba, 2002, 2004; Nelson & Winter, 1982). Other types of agents in sectoral systems are non-firm organisations such as universities, financial organisations, government agencies, and local authorities. In various ways, they support innovation, technological

[12] Innovative success yields profits that can be reinvested in R&D, thereby increasingly the profitability to innovate again.

diffusion, and production by firms, and again their role greatly differs among sectoral systems.

Agents are characterised by specific learning processes, competencies, beliefs, objectives, organisational structures, and behaviours, which interact through the processes of communication, exchange, cooperation, competition, and command. Thus, in a sectoral systems framework, innovation is considered to be a process that involves systematic interactions among a wide variety of actors for the generation and exchange of knowledge relevant to innovation and its commercialisation (Malerba, 2004).

Within sectoral systems, heterogeneous agents are connected in various ways through market and non-market relationships. It is possible to identify different type of relations, linked to different analytical approaches as follows (Malerba, 2004):

(i) Traditional analyses of industrial organisations have examined agents as involved in processes of exchange, competitions, and command (such as vertical integration);

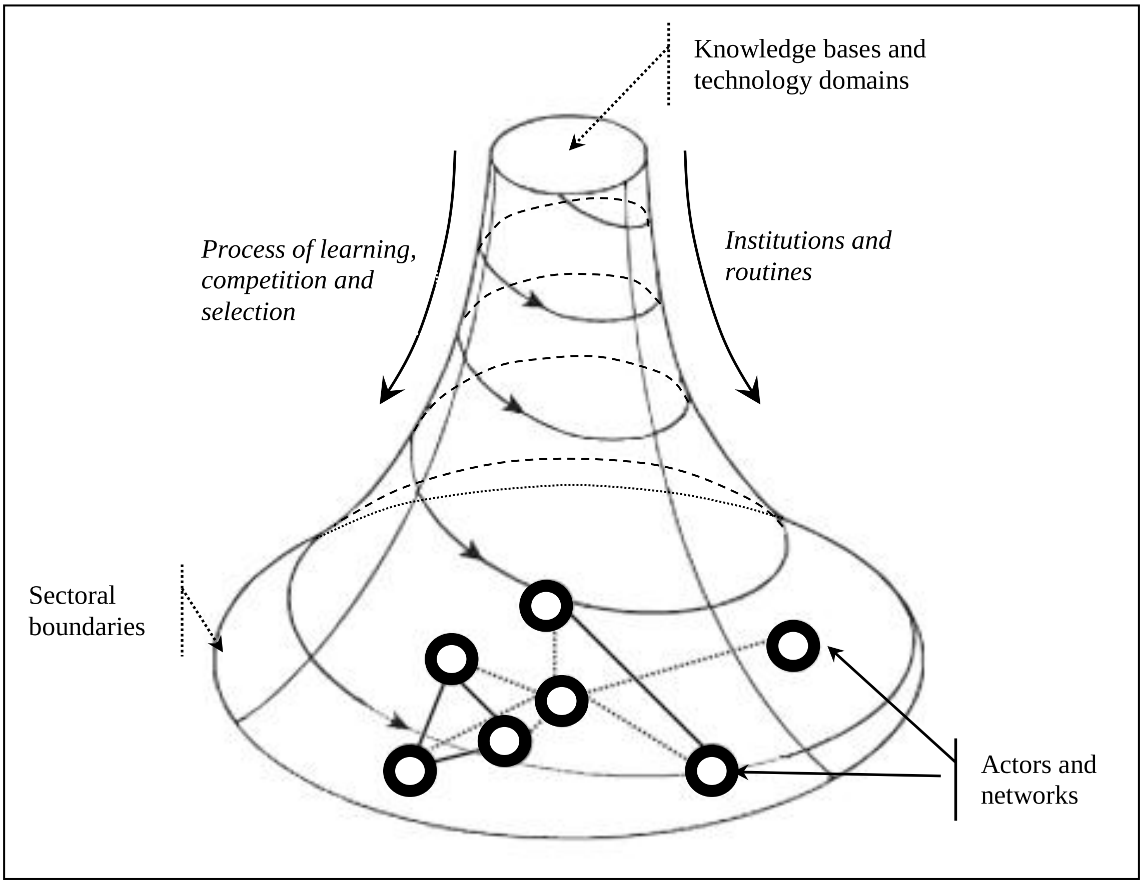
(ii) In more recent analyses, the processes of formal cooperation or informal interaction among firms or among firms and non-firm organisations have been examined in depth. This literature has analysed firms with certain market power, suppliers or users facing opportunistic behaviour or asset specificities in transaction, and firms with similar knowledge having appropriability and indivisibility problems in R&D; and

(iii) The evolutionary approach and the innovation systems literature have also paid a lot of attention to a wide range of formal and informal cooperation and interaction among firms.

c) Institutions – Agents' cognition, actions, and interactions are shaped by institutions, which include their norms, routines, habits, established practices, rules, laws, standards, and so on. Institutions may range from ones that bind or impose enforcements on agents to ones that are created by interaction among agents (such as contracts). Institutions therefore progress from more binding to less binding; from formal to informal (such as patent laws or specific regulations vs. traditions and conventions). A lot of institutions are national (such as the patent system), while others are specific to a particular sector (such as sectoral labour markets or sector specific financial institutions). According to Storper (1998), institutions are persistent and connected sets of rules, formal and informal, that prescribe behavioural roles, constrain activities and shape expectations. They give order to expectations and allow actors to coordinate under conditions of uncertainty.

The relationships of the concepts of three building blocks of SIS are illustrated in Figure 2:3.

Figure 2:3 SIS and its building blocks



In summary, sectoral innovation performance and innovation challenges are various across sector since different sectors have highly specific characteristics. This implicates those industries with different technology level (for instance, the high tech and LMT industries) show different patterns of innovation in their quest for competence development. Drawing upon this standpoint, the following section provides insight into the common characteristics of LMT industries and its technological capabilities development trends. It attempts to provide the readers with the conceptual background of the technological innovations of the LMT industries.

2.4 Innovation in LMT Industry

Literature on sectoral-level innovation studies shows that LMT industries are still relevant sources of innovation in the economy. Despite playing its important roles in prominent roles in growth and employment generation (European Commission, 2006), the capability of LMT industries to advance and use new technologies should not be underestimated (Cox, Frenz, & Prevezer, 2002; Hirsch-Kreinsen, 2008a, 2008b). The LMT industries have been a set of active contributors, rather than passive adopters, of crucial cluster of contemporary paradigm-changing technologies (Mendonça, 2009). LMT, indeed, plays a significant role as a ‘‘carrier industry’’ by incorporating new technologies into the making of new products or implementation of new manufacturing processes (von Tunzelmann & Acha, 2005).

As a corollary, over emphasising the role of high-tech activities by constantly ignoring the importance of LMT industries should be avoided in the process of efficient and sustainable STI-related policies formulation (European Commission, 2006). In fact, the interrelationships of LMT and high-tech industries in an economy are of major importance for the innovativeness of industry in general. Taking example of the industrial development in Europe, the report by European Commission (2006) finds that:

> … that future industrial development in Europe does not depend on making a choice between high-tech and LMT industries. Rather, all these sectors are inextricably linked. In particular, low-tech and medium-low-tech industries are crucially important as customers of high-tech sectors in developed economies. This relationship means that the continued viability of the high-tech sector is inevitably linked to the on-going vitality of LMT industries, a symbiotic relationship that is often overlooked. (p. 18)

Innovation in LMT industries is based on a particular enabling configuration of resources that a company possesses rather than on excellence in R&D alone, and the partnership between the LMT industries and the high-tech industries is crucial (European Commission, 2006). Again, the report by PILOT project makes this point clearly:

> PILOT found that significant innovation might occur in the absence of any activity that could be classed as R&D under commonly-used definitions. Internal organisational practices – knowledge management and personnel policy in particular – play a vital role for innovation in and the innovativeness of LMT firms, while network relations between companies and supportive social networks on a regional level are also important as they are resources for firm capabilities. The analysis also substantiates that interrelationships of mature LMT sectors on the one hand and young high-tech sectors on the other are of major importance for the innovativeness of industry in general. (p. 10)

In addition to R&D intensity, the adoption of a family of indicator of innovativeness such as design intensity, technological intensity, skill intensity, innovation intensity and organisational intensity should be used by analysts to capture the bulk of creativity in all economic sectors, particularly the LMT industries (Cox, et al., 2002; European Commission, 2006; von Tunzelmann & Acha, 2005).[13] In terms of organisational practices in the LMT industries, there is a there is a variety of skill levels and forms of work organisation both among and within LMT firms in a range of sectors, rather than simply the low-skill, hierarchical model that is often assumed (European Commission, 2006). This is supported by strong network relationships between companies and supportive social network on a regional level. To be more precise, technology flows between LMT and high-tech industries are highly dominated by the flows into the LMT (Hauknes & Knell, 2009).

LMT industries are able to organise and innovate their production processes at least as efficiently as high-tech industries. They put a higher emphasis on the quality of their production process which eventually enabling them to success in the global competition via excellent product quality and reasonable process costs (Kirner, et al., 2009). Thus, their innovation activities are concentrated on product innovations (Sundbo, 1996). Most of these product innovations, according to Boly, et al. (2000), are classified as “new to the company”, “product improvement”, “product range enhancement” or “repositioning”.

As non-research intensive industries, innovations of LMT industries are nearly inevitably less technology oriented than those of high tech firms because the latter’s running investments in R&D activities and making the role of technology more

[13] Cox, et al. (2002) suggest that, for understanding innovation processes it is necessary to look at innovations directly, not through R&D expenditures, but for instance through survey questions and case studies. Their point of view are in line with the research methods used in this study, which will be describe in more detail in chapter 4 of this thesis.

explicitly central to commercial success (von Tunzelmann & Acha, 2005). The LMT industries innovation strategies move within a spectrum of incremental and architectural innovation, which is commonly be referred to as step-by-step product development (Hirsch-Kreinsen, 2008a). In many cases LMT industries products are more or less technologically mature, often they are standard parts made of cheap materials, they are made in big production runs and are characterised by low complexity (Hirsch-Kreinsen, 2008b). Table 2:2 compares the main features of innovation trends between LMT and high-tech and medium-high-tech (HMT) industries.

Table 2:2 Innovation modes in LMT and HMT sectors

	LMT	HMT
Key drivers	New technologies - market demand	S&T driven in combination with market demand
Typical strategies	Broad spectrum: incremental - architectural	Broad spectrum, high relevance of radical innovations, main focus on product innovations
Size of enterprises	Mostly SMEs	Mostly large enterprises
Knowledge base	Internal: high relevance of practical knowledge	Internal: high relevance of codified knowledge in combination with practical knowledge
	External: codified knowledge	External: wide variety of sources for codified knowledge transcending sectoral boundaries
Company capabilities and competences	Mostly management-based and unskilled workers; centralised competence base	Management, engineers, experts, skilled workers; broad competence base
Network relations	Cooperation with high-tech and specialised suppliers, consultants, etc., partly with customers, limited inclination to cooperate	Wide variety of external partners stemming from various societal sectors (national and international); intensive cooperation with external partners
Institutional embeddedness	Loosely coupled with most institutional conditions apart from industrial structure	In many cases pronounced coupling with societal institutions; high relevance of innovation policy

Source: Hirsch-Kreinsen (2008a)

As LMT industries are quite generally dominated by the SMEs (Hirsch-Kreinsen, 2008a; Kirner, et al., 2009), understanding the nature of the technological innovation among the SMEs is crucial in order to capture the comprehensive view of the LMT industries' innovation trends. Drawing upon this standpoint, the following section will analyse the roles and functions played by the SMEs in an innovation systems.

2.5 SMEs and Innovation Systems

This section reviews literature on the relationship between SMEs and innovation systems. It begins with the review of the importance of firm's technological innovation and followed by the technological innovation and the nature of SMEs. The third part reviews the linkages capabilities in technological innovative SMEs. The last part reviews the roles of social capital in SMEs technological capabilities development.

2.5.1 The Importance of Firm's Technological Innovation

Hall (1994) suggests that to understand the innovation process, it is important to understand how firms work. A firm is defined as a decision making unit engaged in production. It is at the level of firm that the decisions are made to introduce new technology into production and where much new technology is developed in the pursuit of product and process innovation. Although the literature on the importance of firm's technological capabilities is extensive, there is a general consensus that one stream of efforts on developing and leveraging the level of competency of firms is by strengthening their technological innovation capabilities.[14] Arguably, firms that are able to survive and prosper in the decades ahead will be those who are able to manage technological innovation and derive business from it. Those that do not will suffer an untimely demise as apparently described by Freeman in his famous quote ‘not to innovate is to die’. In other words, as Thamhain (1996) reminds us, firms that are able to leverage on technological innovations to achieve superior performance, new features, and lower costs will add the largest value to their products and eventually compete more effectively in the market.

Ettlie (2000) believes that technology-induced changes in the workplace profoundly affect organisational effectiveness, careers, and workplace comfort. It is critical to address the issues of technological change within firms for three primary reasons. Firstly, technology-driven change is everywhere and always present. Secondly, competitors use technology as part of their success strategies. Thirdly, value-capture from new technology is challenging and never guaranteed. In line with Ettlie’s viewpoints, Chiesa (2007) writes:

> Firms outperforming competitors often derive their success from innovation and in many cases such innovation is technology based. Creating new product, processes and services is recognised as a major source of competitive advantage and technology is often the enabler of such innovation. (p. 1)

[14] For instance, Porter (1985) recognise that technology is the determinant of the industrial structure and therefore affect the profitability within the industry, and technology affects a firm’s potential to generate competitive advantages and can be at the basis of the firm’s positioning within the business area.

According to Freeman (1982), changes in technology, market conditions and the advances of their competitors, compel firms to try and keep pace in one way or another:

> If firms wish to survive despite all their uncertainties about innovation, most firms are on an innovative treadmill. They may not wish to be offensive innovators, but they can often scarcely avoid being defensive or imitative innovators. (p. 170) [15]

2.5.2 Technological Innovation and the Nature of SMEs

According to Rothwell & Dodgson (1994), the innovatory advantages of small firms are those of entrepreneurial dynamism, internal flexibility and responsiveness to changing circumstances, that is, the behavioural advantages. On the contrary, the innovatory disadvantages of small firms are those of financial and resources, that is, the material disadvantages. Table 2:3 lists the advantages and disadvantages generally ascribed to small firms.

[15] An ‘offensive’ innovation strategy is one designed to achieve technical and market leadership by being ahead of competitors in the introduction of new products. The firm pursuing an ‘offensive’ strategy will be normally be highly research intensive, since it will usually depend to a considerable amount on in-house R&D. On the contrary, the defensive’ innovators do not wish to be the first of the world, but neither do they wish to be left behind by the tide of technical change. For ‘imitative’ innovators, they do not aspire to leap-forging or even keeping up with the game. It is content to follow way behind the leaders in establishing technologies, often a long way behind. Besides, Freeman also identified another three categories of innovation strategy, namely dependent strategy, traditional strategy, and opportunist strategy. Freeman (1982: 170-183) offers an excellent explanation on innovation strategies of the firms.

Table 2:3 Innovatory advantages and disadvantages of small firms

Elements	Advantages	Disadvantages
Management	– Little bureaucracy; entrepreneurial management; rapid decision-making; risk-taking; organic style.	– Entrepreneurial managers often lack formal management skills.
Communication	– Rapid and effective internal communication; informal networks.	– Lack of time and resources to forge suitable external S&T network.
Marketing	– Fast reaction to changing market requirement; can dominate narrow market niches.	– Market start-up abroad can be prohibitively costly.
Technical manpower	– Technical personnel well plugged in to other departments.	– Often lack high-level technical skills. Full-time R&D can be too costly. (Need technical specialists for external links.) Can suffer diseconomies of scope in R&D.
Finance	– Innovation can be less costly in SMEs; SMEs can be more "R&D efficient".	– Innovation represents a large financial risk; inability to spread risk; accessing external capital for innovation can be a problem. Cost of capital can be relatively high.
Growth	– Potential for growth through 'niche strategy' techno/market leadership (differentiation strategy).	– Problems in accessing external capital for growth; entrepreneurs often unable to manage growth.
Regulations	– Regulations sometimes applied less stringently to SMEs.	– Often cannot cope with complex regulations; unit costs of compliance can be high; often unable to cope patenting system; high opportunity costs in defending patents.
Government schemes	– Many schemes have been established to assist innovation in SMEs.	– Accessing government schemes can be difficult: high opportunity costs. Lack of awareness of available schemes. Difficult in coping with collaborative schemes.
Learning ability	– Capable of 'fast learning', and adapting routines and strategies. If new, no 'unlearning' problems.	
Organisation	– Generally simple and focused. 'Organic' form.	
Joint ventures/strategic alliance	– Can prove attractive partner if technological leader.	– Little management experience; power imbalance if collaborating with large firms.
Supplier relations		– Can exert little control over suppliers.

Source: Rothwell & Dodgson (1994)

For Tidd, Bessant & Pavitt (2005), unlike large firms, small firms tend to be specialised rather than diversified in their technological competencies and product ranges. Most of the innovating small firms in the traditional sectors such as textiles, wood products, food products, etc are categorised as supplier dominated firms, in which the process of integration and adaptation of innovators by suppliers are the main sources of competitive advantages. Tidd and his colleagues also reveal that, in terms of the accomplishment of innovation strategy, deliberate organisational processes to integrate the technical function with production, marketing, strategy and resource allocation are of less central importance in large firms than in small firms. The characteristics of senior managers - their training, experience, responsibilities and external linkages - play a central role in this sense. In particular, their level of technical and organisational skills will determine whether or not they will be able to develop and commercially exploit a firm-specific technological advantage. Table 2:4 contrasts the differences between large and small firms in how certain key tasks to innovation strategies are accomplished.

Besides, one of the focal points of innovative SMEs, as revealed by Tidd and his colleagues is that they are likely to have diverse and extensive linkages with a variety of external sources of innovation in order to form a positive association between the level of external scientific, technical and professional inputs and the performance of SMEs.[16] However, such relationships are not without cost, and the management and exploitation of these linkages can be difficult for SMEs which have limited technical and management resources. The next section provides some insights into the perspectives of SMEs' linkages capabilities in their quest for technological innovation capabilities development.

[16] However, this is rarely the case unless they are science based SMEs, that is, the tiny minority.

Table 2:4 Innovation strategies in large and small firms

Strategic tasks	*Large firms*	*Small firms*
Integrating technology with production and marketing	• Organisational design • Organisational processes for knowledge flows across boundaries	• Responsibilities of senior managers
Monitoring and assimilating new technical knowledge	• Own R&D and external networks	• Trade and technical journals • Training and advisory services • Consultants • Suppliers and customers
Judging the learning benefits of investment in technology	• Judgement based on formal criteria and procedures	• Judgement based on qualifications and experience of senior management
Matching strategic style with technological opportunities	• Deliberate organisational design	• Qualifications of managers and staff

Source: Tidd, et al.(2005)

2.5.3 Linkages Capabilities in Technological Innovative SMEs

As discussed in the earlier sections, technological innovation (both product and process) is a complex and interactive continuous process. It involves a series of alternating stimulus-response exchanges among the prominent actors in the system. Thus, a reasonably sound linkage between firm and various actors such as customers, suppliers, competitors, government machinery, research laboratories and financial institutions, is crucial to determine the overall performance of a firm’s innovation capabilities. As emphasized by Trott (2002), the interactions of those functions both within the organisation and with the external environment are important.

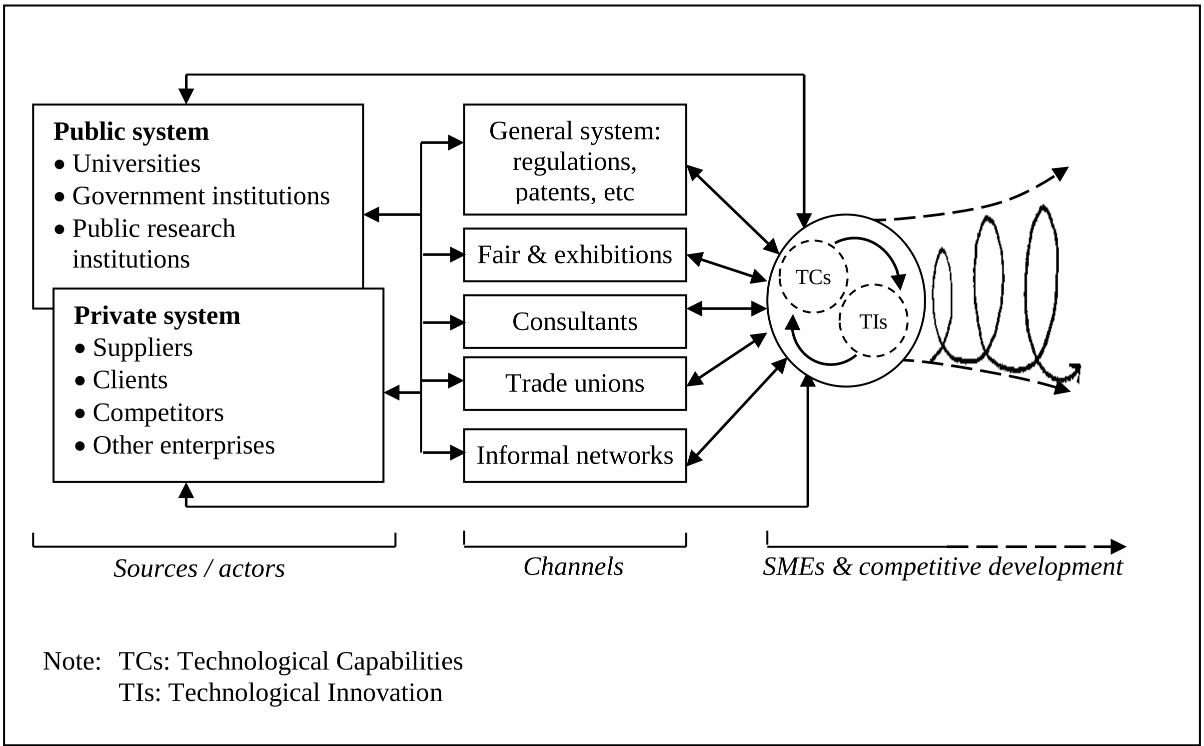
According to Khalil (2000), the technological innovation process requires the integration of inventions and existing technologies to bring innovation to the marketplace. In their efforts to develop technological capabilities, firms draw heavily upon external technological resources such as information, skills and specialised technical services through market and non-market linkages (Jomo & Felker, 1999). As technological innovation rarely occurs through the activities of single firms, it is more commonly a result of inputs from a variety of firms, working together as customers and suppliers, or in various forms of alliances or technological collaborations (Dodgson, 2000). According to Lall, Teitel, Navaretti, & Wignaraja (1994), activities pertaining to the development of linkages capabilities can be grouped into three categories in accordance to the degree of their complexity or difficulty, namely: (i) experience based (basic degree) - local procurement of goods and services, information exchange with suppliers; (ii) search based (intermediate degree) - technological transfer of local suppliers, coordination design, science and technology links; and (iii) research based (advanced degree) - turnkey capability, cooperative R&D, licensing own technology to others.

Also, drawing upon “evolutionary theories”, Lall (1992) further suggests that technological capabilities are highly idiosyncratic at the firm-level. A similar framework has been used by Malerba (2002, 2004) in establishing the concept of SIS. For Marleba (2002), innovation greatly differs across sectors in terms of characteristics, sources, actors involved, the boundaries of the process, and the organisation of innovative activities. These heterogeneous actors are linked (through both market and non-market relationships) through processes of communication, exchange, cooperation, competition and command. A somewhat similar idea of recognising networks from the theory of systems, where the whole is greater than the sum parts, is also propounded by Tidd, et al. (2005).

In the case of SMEs, OECD (1993) asserts that internal R&D alone is not sufficient in fostering SMEs' competitiveness, as it can only feed and stimulate through contacts with external parties. External sources of information include public or private system to which the enterprises may have access. In addition, scientific and technological information is obviously not transferred solely, or even mainly, directly from the primary sources mentioned above to SMEs. Rather, it goes through a whole series of channels: the general system of scientific and technological information, trade fairs, consultancy firms and a whole series of non-formal channels and networks. Figure 2:4 presents the possible sources and channels for SMEs technological innovation development.[17]

[17] However, this model is over-emphasising the "public system". For a much more sensible model, please see "The SME-centric universe" in Figure 2:5.

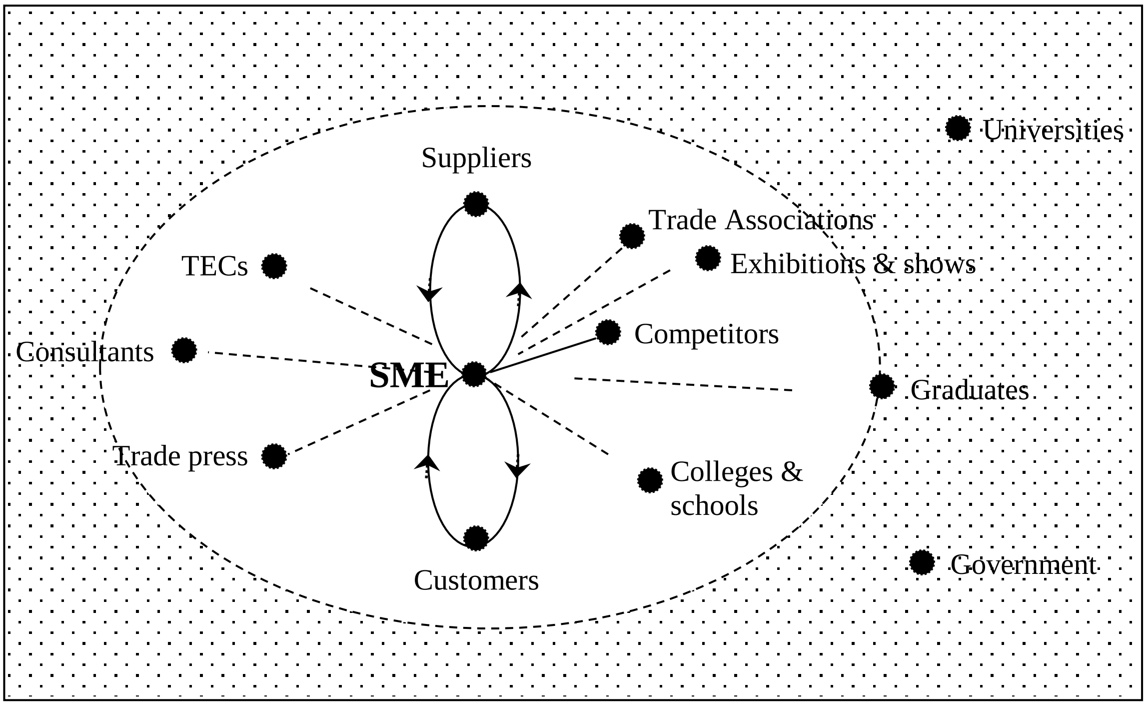
Figure 2:4 Sources and channels for SMEs technological innovation development



Source: Adapted and modified from OECD (1993, 1997)

The most important direct interactions are those with suppliers of inputs or capital goods, competitors, customers, consultants and technology suppliers. Technological linkages also occur with firms in unrelated industries, technology institutes, extension services and universities, industry associations, and training associations (Lall, 2000). In the case of small firms, Malecki (1997) reveals that small firms use networks as ‘antenna’ and ‘filters’ of information. They have extensive contact networks, comprising mainly business contracts associated with commercial organisations, such as customers, consultants and other managers. However, all these networks are especially likely to be local. In Woolgar, Vaux, Gomes, Ezingeard & Grieve (1998) “SME-centric universe” framework, as illustrated in Figure 2:5, small firms interact most often and most closely with their immediate business environment, that is, customers and suppliers, and to a lesser extent their competitors. Universities and government organisations lie outside of a small firm's attention.

Figure 2:5 The SME-centric universe



Source: Woolgar, et al. (1998)

In the case of Malaysia, the transition from industrialisation based on technology assimilation to more advanced, research-based forms of innovation, appears to be delayed and difficult (Felker & Jomo, 2007). There is a small group of modern SMEs that are integrated into the modern sector, using modern technologies, and acting as sub-contractors and suppliers to export market-oriented multinational corporations (MNCs). The bulk of the industry sector, however, consists of small traditional firms employing low-technology and low-skill technologies, and producing low-value products for the local market. The wood product industry is an exception, in which the numbers of

SMEs serving the export market are considerable and they use modern technologies efficiently (Lall, 1999).

2.5.4 SMEs and Social Capital

Evidence from SME and firm level studies suggests that a key driver for small firms to be innovative and competitive is that they should have social capital capabilities, that is, the ability to establish connections in a social network, and the trust, reciprocity, and resource sharing qualities of those connections (Fuller & Tian, 2006; Landry, Amara, & Lamari, 2002; Partanen, Möller, Westerlund, Rajala, & Rajala, 2008; Pennings, Lee, & Witteloostuijn, 1998; Ruuskanen, 2004; Walker, Kogut, & Shan, 1997; Westlund, 2004; Woolcock, 1998; Wu & Leung, 2005). For Cooke & Wills (1999), social capital is a communal property involving civic engagement, associational membership, high trust, reliability and reciprocity in social networks. It is capable of being identified in social, political and economic contexts, often associated with strong communities. The roles of social capital as the norms and networks facilitating collective action for mutual benefit among firms are further ascertained by Woolcock (1998):

> I contend that development outcomes are shaped by the extent to which basic social dilemmas at the micro and macro level are resolved. Positive outcomes are attained to the extent that both embedded and autonomous social relations prevail at both levels. This happens when people are willing and able to draw on nurturing social ties (i) within their local communities; (ii) between local communities and groups with external and more extensive social connections to civil society; (iii) between civil society and macro-level institutions; and (iv) within corporate sector institutions. All four dimensions must be present for optimal developmental outcomes. (p. 186)

The social capital of an enterprise is made up of three types of actors, namely the enterprises themselves and their organisations, the politically governed sector, and the civil society and its organisations (Westlund, 2004). Table 2:5 provides a schematic picture of the component parts of enterprise-based internal and external social capital.

Table 2:5 Component parts of enterprise-based social capital

Social capital internal to the enterprise	The enterprise's external social capital		
Links/relations filled with attitudes, norms, traditions etc. that are expressed in the form of:	Production-related social capital	Environment-related social capital	Market-related social capital
- Company spirit - Climate for cooperation - Methods for using tacit knowledge, codifying knowledge, product development, conflict resolution, etc.	Links/relations to suppliers, product users, partners in cooperation and development	Links/relations to the local/regional environment, to political decision - makers etc. (Lobby capacity, etc.)	Trademarks and other general customer relations

Source: Westlund (2004)

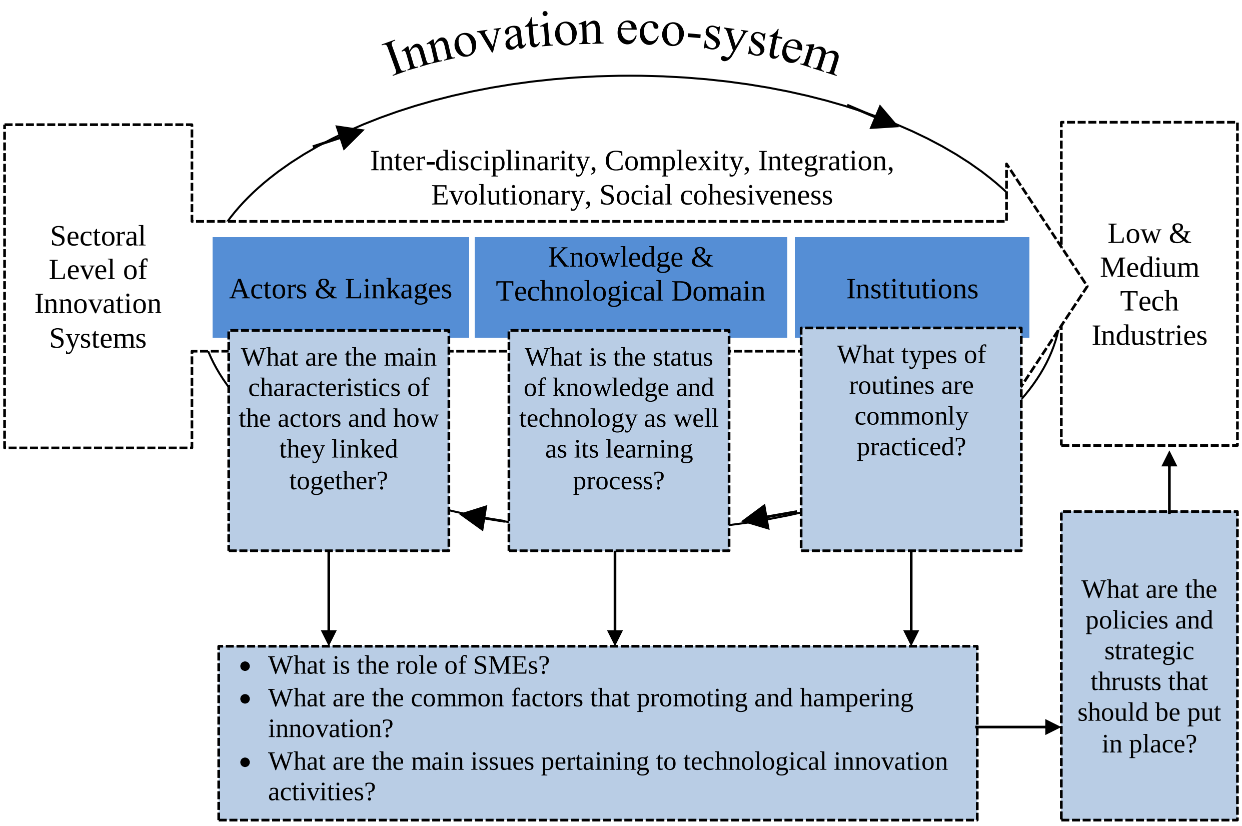
From the perspective of innovation systems framework, social capital plays its important role in facilitating the process of learning and knowledge exchange among actors (Kallio, Harmaakorpi, & Pihkala, 2010; Lundvall, 1988, 2002, 1992). Lundvall (1988) stresses that innovation rarely occurs in isolation, it is a highly interactive process of "learning by doing" activities within the organisations as well as the marketplaces. In this regard, Lundvall (1992) emphasises that cultural space is important in the sense that it allows the establishment of institutional framework, that is, 'sets of habits, routines, rules, norms and laws which regulate the relations between people and shape human interaction' in innovation and learning. Moreover, since learning and innovation are interactive processes, its success is closely dependent on trust and other elements of social cohesion. For Lundvall (2002), social cohesion is an important aspect particularly in the case of the competitiveness of small countries that depends on their ability to create and facilitate learning:

> Cohesiveness, which can also be said to be one important element of "social capital", has such great importance in the learning economy because effective learning (unlike the processing of information) presupposes trust and cooperation. While small countries may remain handicapped in some product areas dominated by formal knowledge, they can penetrate in other knowledge-intensive areas anchored in interactive learning processes. (p. 27)

For Spence, Schmidpeter & Habisch (2003), SMEs engage much social capital because of a constant and essential exchange with their economic and social environment. The SME owner-manager investing in social capital because: (a) they stabilise mutual expectation and enable collective action (trust), (b) the form a kind of insurance and, (c) they give access to relevant information. In summary, social capital can take different forms, primarily trust, norms, and networks. Trust is developed over time through repeated series of interactions. Norms of appropriate behaviour also develop over time as a result of a series of interactions and exchange of resources. Also, networks develop as actors develop reliable and effective communication channels across organisational boundaries (Landry, et al., 2002).

Based on the literature and argument established from section 2.3 to section 2.5, as well as the research questions formed in section 1.3, Figure 2:6 exhibits the conceptual framework of this research.

Figure 2:6 Conceptual framework



2.6 Summary

This chapter has reviewed the relevant literature on the patterns and process of technological innovation. The review began with an overview of the nature of technological innovation activities which are widely characterised as inter-disciplinarity, complexity, integration and evolutionary. Besides, technological innovation has to be viewed as a systemic continuous progress, rather than a one-off event. Drawn upon these viewpoints, literature in sectoral innovation systems studies has suggested three building blocks that comprehensively addresses the sectoral's innovation activities, namely technological domain and knowledge-based, actors and linkages, and institutions. Like other innovation systems approaches, SIS is mainly developed on the basis of the importance of continuous learning process, interactive networking, and both formal and informal common practices amongst the innovation agents.

Literature on innovation patterns in LMT suggests that efficient and sustainable policies to support innovativeness should be non-discriminatory and the importance of LMT actors as an important segment of a country's innovation structure should be acknowledged. However, as non-research intensive industries, LMT industries are always getting less attention in the innovation studies compared to those from research intensive high-tech industries. Hence, this study attempts to fill this gap by investigating the patterns of technological innovation in a LMT industry in a developing country. As LMT industries are quite generally dominated by the SMEs, this study is also expected to contribute to existing literature and knowledge on SMEs technological capabilities development, particularly from the aspect of linkages capabilities and social capital capabilities of the firms. The following chapter will explore and analyse the literatures on both global and Malaysia's wooden furniture industry by adopting the SIS approach.